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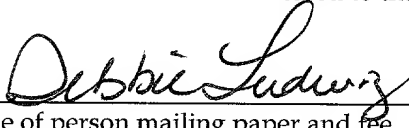
REAL TIME DATA CONVERSION FOR A DIGITAL DISPLAY

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## REAL TIME DATA CONVERSION FOR A DIGITAL DISPLAY

### BACKGROUND

[0001] The present invention relates generally to optical systems, and more particularly, to a system and method for converting and displaying image data in real time in a photolithography system.

[0002] Digital systems, such as those used in maskless photolithographic processing, require image data to be processed and projected onto a subject. The amount of image data that must be processed is generally relatively large, and increases when higher resolutions are desired. Higher resolution may be desirable for a number of reasons. For example, a line may have a minimum width when projected at a certain resolution. This minimum width may be undesirable, for instance, because it limits the number of lines which may be projected onto the subject. Using a higher resolution may allow the line to be projected using a smaller minimum width, and so more lines may be projected onto the subject. In photolithography, the subject may be a substrate and the projected image may be a mask. Therefore, a higher resolution enables a more detailed mask to be projected onto the substrate without altering the size of the substrate.

[0003] A two dimensional image, such as may represent a photolithography mask, may be thought of as lying in a coordinate system having two axes. One common example of such a coordinate system utilizes an x axis and a y axis. An

image is generally displayed through or from a projection device, such as a pixel panel, so that the edges of the image are aligned with the x and y axes of the pixel panel. In other words, the top and bottom edges of the image may be parallel to the x axis and perpendicular to the y axis, while the left and right edges may be parallel to the y axis and perpendicular to the x axis. This allows relatively simple techniques to be used to design and store the image in the computer system, since it can be stored in a memory array using techniques well known in the art and projected by the pixel panel.

[0004] However, in applications where the image is projected onto a subject, the resolution of the projected image is constrained by the fact that it is limited to the resolution available on the pixel panel. In applications such as maskless photolithography, this results in a maximum resolution which is limited by the resolution of the original image, the resolution of the pixel panel, the transfer rate of the system, the available storage capacity, and similar factors.

[0005] Therefore, certain improvements are needed in converting and displaying image data. For example, it is desirable to convert an image in real time for projection upon a subject. It is also desirable to manipulate the image in order to project the image as desired. It is also desirable to use minimal storage space, to transfer data as efficiently as possible, to provide high light energy efficiency, to provide high productivity and resolution, and to be more flexible and reliable.

## **SUMMARY**

[0006] A technical advance is provided by a novel system and method for extracting and manipulating image data. In one embodiment, the system includes a first memory operable to store the image data and a processing device connectable to the first memory, the processing device operable to manipulate

the image data. The system also includes a second memory accessible to the processing device, the second memory operable to buffer the manipulated data. A pixel panel positioned in a first plane is operable to receive the buffered data and project the data upon a subject positioned in a second plane substantially parallel to the first plane, where the pixel panel is positioned at an angle relative to the subject.

[0007] In another embodiment, a method for converting image data in real time for projection onto a subject retrieves at least a portion of the image from a memory. The method calculates at least one address for the image portion, the calculation operable to determine the position of the image portion on a pixel panel positioned in a first plane and rotated relative to the subject, where the subject is positioned in a second plane that is substantially parallel to the first plane. The image portion is transferred to a buffer and transferred from the buffer to the pixel panel.

[0008] In yet another embodiment, a point array including a plurality of points for projection onto a subject is rotated. The points are arranged in a plurality of columns and rows and projectable onto the subject along scan lines. A number of rows in the array is determined, as is a first distance between two scan lines. A number of redundant points is established, the redundant points falling on a single scan line. An angle is calculated using the number of rows and the number of redundant points such that the first distance is achieved when the point array is rotated to coincide with the angle.

## **BRIEF DESCRIPTION OF THE DRAWINGS**

[0009] Fig. 1 is a diagrammatic view of an improved digital photolithography system for implementing various embodiments of the present invention.

[0010] Fig. 2 illustrates an exemplary point array aligned with a subject.

[0011] Fig. 3 illustrates the point array of Fig. 2 after being rotated relative to the subject.

[0012] Fig. 4 illustrates a point array rotated so that no points fall on a single vertical line.

[0013] Fig. 5 illustrates the point array of Fig. 4 rotated so that two points fall on a single vertical line.

[0014] Fig. 6 illustrates the point array of Fig. 5 rotated so that three points fall on a single vertical line.

[0015] Fig. 7 illustrates a point array overlaid on an exemplary memory grid.

[0016] Fig. 8 is an exploded view of a portion of the point array of Fig. 7 illustrating individual points in a series of frames.

[0017] Fig. 9 illustrates the point array of Fig. 7, with a portion of a second point array overlay visible.

[0018] Fig. 10 is an example of an image portion projected at two different resolutions.

[0019] Fig. 11 is a diagrammatic view of one embodiment of an exemplary system for converting image data for display on a rotated pixel panel.

[0020] Fig. 12 is a diagrammatic view of another embodiment of an exemplary system for converting image data for display on a rotated pixel panel.

[0021] Fig. 13 is a flow chart illustrating a process for retrieving image data from memory and projecting it on a rotated pixel panel.

[0022] Fig. 14 is a diagrammatic view of yet another embodiment of an exemplary system for converting image data for display on a rotated pixel panel.

## DETAILED DESCRIPTION

[0023] The present disclosure relates to optical devices and more particularly to converting and displaying image data in a photolithography system. It is understood, however, that the following disclosure provides many different embodiments, or examples, for implementing different features of the invention. Specific examples of components and arrangements are described below to simplify the present disclosure. These are, of course, merely examples and are not intended to limit the invention from that described in the claims. In addition, the present disclosure may repeat reference numerals and/or letters in the various examples. This repetition is for the purpose of simplicity and clarity and does not in itself dictate a relationship between the various embodiments and/or configurations discussed.

[0024] Referring now to Fig. 1, a maskless photolithography system 100 is one example of a system that can benefit from the present invention. In the present example, the maskless photolithography system 100 includes a light source 102, a first lens system 104, a computer aided pattern design system 106, a pixel panel 108, a panel alignment stage 110, a second lens system 112, a subject 114, and a subject stage 116. A resist layer or coating 118 may be disposed on the subject 114. The light source 102 may be an incoherent light source (e.g., a Mercury lamp) that provides a collimated beam of light 120 which is projected through the first lens system 104 and onto the pixel panel 108.

[0025] The pixel panel 108, which may be a digital mirror device (DMD), is provided with digital data via suitable signal line(s) 128 from the computer aided pattern design system 106 to create a desired pixel pattern (the pixel-mask pattern). The pixel-mask pattern may be available and resident at the pixel panel 108 for a desired, specific duration. Light emanating from (or through) the pixel-mask pattern of the pixel panel 108 then passes through the second lens system

112 and onto the subject 114. In this manner, the pixel-mask pattern is projected onto the resist coating 118 of the subject 114.

[0026] The computer aided mask design system 106 can be used for the creation of the digital data for the pixel-mask pattern. The computer aided pattern design system 106 may include computer aided design (CAD) software similar to that which is currently used for the creation of mask data for use in the manufacture of a conventional printed mask. Any modifications and/or changes required in the pixel-mask pattern can be made using the computer aided pattern design system 106. Therefore, any given pixel-mask pattern can be changed, as needed, almost instantly with the use of an appropriate instruction from the computer aided pattern design system 106. The computer aided mask design system 106 can also be used for adjusting a scale of the image or for correcting image distortion.

[0027] In some embodiments, the computer aided mask design system 106 is connected to a first motor 122 for moving the stage 116, and a driver 124 for providing digital data to the pixel panel 108. In some embodiments, an additional motor 126 may be included for moving the pixel panel. The system 106 can thereby control the data provided to the pixel panel 108 in conjunction with the relative movement between the pixel panel 108 and the subject 114.

[0028] Efficient data transfer may be one aspect of the system 106. Data transfer techniques, such as those described in U.S. provisional patent application Serial Number 60/278,276,453, filed on March 22, 2001, and also assigned to Ball Semiconductor, Inc., entitled "SYSTEM AND METHOD FOR LOSSLESS DATA TRANSMISSION" and hereby incorporated by reference as if reproduced in its entirety, may be utilized to increase the throughput of data while maintaining reliability. Some data, such as high resolution images, may

present a challenge due in part to the amount of information needing to be transferred.

[0029] Referring now to Fig. 2, a pixel panel 210 comprising a DMD, which may be present in a system such as that described above with reference to Fig. 1, is illustrated. The pixel panel 210, which is shown as a point array for purposes of clarification, projects an image (not shown) upon a substrate 212. The substrate is moving in a direction indicated by an arrow 214. Alternatively, the point array 210 could be in motion while the substrate 212 is stationary, or both the substrate 212 and the point array 210 could be moving simultaneously. The point array 210 is aligned with both the substrate 212 and the direction of movement 214 as shown. A distance, denoted for purposes of illustration as "D", separates individual points 216 of the point array 210. In the present illustration, the point distribution that is projected onto the subject 212 is uniform, which means that each point 216 is separated from each adjacent point 216 both vertically and horizontally by the distance D.

[0030] As the substrate 212 moves in the direction 214, a series of scan lines 218 indicate where the points 216 may be projected onto the substrate 212. The scan lines are separated by a distance "S". Because of the alignment of the point array 210 with the substrate 212 and the scanning direction 214, the distance S between the scan lines 218 equals the distance D between the points 216. In addition, both S and D remain relatively constant during the scanning process. Achieving a higher resolution using this alignment typically requires that the point array 210 embodying the DMD be constructed so that the points 216 are closer together. Therefore, the construction of the point array 210 and its alignment in relation to the substrate 212 limits the resolution which may be achieved.



[0031] Referring now to Fig. 3, a higher resolution may be achieved with the point array 210 of Fig. 2 by rotating the DMD embodying the point array 210 in relation to the substrate 212. As illustrated in Fig. 3, although the distance D between the points 216 remains constant, such a rotation may reduce the distance S between the scan lines 218, which effectively increases the resolution of the point array 210. The image data that is to be projected by the point array 210 must be manipulated so as to account for the rotation of the point array 210. The manipulation should include an angle  $\theta$  between an axis 310 of the rotated point array 210 and a corresponding axis 312 of the substrate.

[0032] The magnitude of the angle  $\theta$  may be altered to vary the distance S between the scan lines 218. If the angle  $\theta$  is relatively small, the resolution increase may be minimal as the points 216 will remain in an alignment approximately equal to the alignment illustrated in Fig. 2. As the angle  $\theta$  increases, the alignment of the points 216 relative to the substrate 212 will increasingly resemble that illustrated in Fig. 3. If the angle  $\theta$  is increased to certain magnitudes, various points 216 will be aligned in a redundant manner and so fall onto the same scan line 218. Therefore, manipulation of the angle  $\theta$  permits manipulation of the distance S between the scan lines 218, which affects the resolution of the point array 210. It is noted that the distance S may not be the same between different pairs of scan lines as the angle  $\theta$  is altered.

[0033] Referring now to Fig. 4, a pixel panel 410 (again shown as a point array) comprising M columns by N rows is illustrated. In the present example, M = 16 and N = 12. The point array 410 may represent an image, such as an image used in a maskless photolithography system. Each column and row includes a plurality of individual points 416. For purposes of illustration, each point 416 will be referenced by its column/row position in the point array 410 when it is important to identify a particular point. For example, the point 416

located in the second column, fourth row, will be referred to as point (2,4). Each point 416 is separated by a distance "D" from the corresponding point in the adjacent columns and rows. For example, the point (10,11) is a distance D from point (9,11), point (11,11), point (10,10), and point (10,12). Therefore, the total distance between the first and last points 416 in each row is equal to  $(M-1)*D$ , while the total distance between the first and last points 416 in each column is  $(N-1)*D$ .

[0034] An angle  $\theta$  represents the angle between an axis 420 of the point array 410 and a corresponding axis 422 of a subject 412 (not shown). A series of scan lines 418 indicate where the points 416 may be projected onto the subject 412. Depending on the angle  $\theta$ , the scan lines 418 may be separated by a constant distance or by varying distances, as described below. When no redundancy occurs (i.e., no two points 416 from the array 410 may fall on the same scan line 418), a variable "K" is equal to one, signifying a one to one correspondence between a point 416 and a scan line 418. A series of relationships may be developed using the values M, N, K, D and  $\theta$ . The relationships enable various aspects of the rotation of the array 410 to be calculated in order to achieve a desired result.

[0035] A distance "B", which designates the distance between the scan lines 418 of two adjacent points 416 in a row when the array 410 is rotated to angle  $\theta$ , may be calculated by setting B equal to  $D*\cos(\theta)$ . A distance "C" represents the distance between the scan lines 418 of two adjacent points 416 in a column when the array 410 is rotated to angle  $\theta$ , and may be calculated by setting C equal to  $D*\sin(\theta)$ . A distance "A" represents the distance between the scan lines 418 of the point 416 in the bottom row of a column and the point 416 in the top row of the next column when the array 410 is rotated to angle  $\theta$ . For example, the scan

lines associated with the point (15,12) and the point (16,1) are separated by the distance A, which may be calculated as  $B-(N-1)*D*\sin(\theta)$ .

[0036] In the present example, the points 416 are uniformly distributed (i.e., the same distance separates each point 416 from the adjacent points 416 when projected onto the subject). When this uniformity occurs,  $A = C = D*\sin(\theta)$  and  $\tan(\theta) = K/N$ .

[0037] Using one or more of these relationships, the angle  $\theta$  can be calculated to achieve a desired distance between the scan lines 418. For example, when  $N = 600$  and  $K = 1$ , then  $\theta = \tan^{-1}(1/600) \approx 0.0955$  degrees. Therefore, rotating the point array 410 by 0.0955 degrees will enable the array 410 to be projected with the desired characteristics of A, B, C and D.

[0038] It should be noted that choosing a uniform distribution of points 416 may simplify the calculation of  $\theta$  and its effect on the resolution provided by the spacing of the scan lines 418. This may be accomplished by selecting a desired resolution so that  $A = C = D*\sin(\theta)$ .

[0039] Referring now to Fig. 5, the point array 410 of Fig. 4 is illustrated with a larger angle  $\theta$ . In contrast to Fig. 4, the present figure depicts an example where  $K = 2$ . This means that there is redundancy such that two points 416 from the array 410 fall on the same scan line 418 (i.e., there is a two to one correspondence between two points 416 and a scan line 418). For example, the point (8,1) and the point (7,7) are associated with the same scan line 418. Such redundancy may be desirable if, among other reasons, the DMD includes a faulty mirror. If the mirror associated with one of the points on a scan line fails, a redundant mirror may be utilized to ensure the point is properly projected.

[0040] The distance "D" separates each point 416 from the adjacent points 416. The total distance between the first and last points 416 in each row is equal

to  $(M-1)*D$ , while the total distance between the first and last points 416 in each column is  $(N-1)*D$ . Using  $M$ ,  $N$ ,  $K$ ,  $D$  and  $\theta$ , a series of relationships may be developed for  $K=2$ . As in Fig. 4, the relationships may enable various aspects of the rotation of the array 410 to be calculated in order to achieve a desired result.

**[0041]** The distance "B" designates the distance between the scan lines 418 of two points in a row separated by another point 416 when the array 410 is rotated to angle  $\theta$ . For example, the point (14,12) is separated from the point (16,12) by the distance  $b$ , which may be calculated as  $B = K*D*\cos(\theta)$ . The distance "C" may be calculated as  $C = D*\sin(\theta)$ . The distance "A" may be calculated as  $A = B - (N-1)*D*\sin(\theta)$ .

**[0042]** When the points 416 are uniformly distributed (i.e., the same distance separates each point 416 from the adjacent points 416 when projected onto the subject), then  $A=C=D*\sin(\theta)$  and  $\tan(\theta) = K/N$ .

**[0043]** Using one or more of these relationships, the angle  $\theta$  can be calculated to achieve a desired distance between the scan lines 418. For example, when  $N$  (the number of rows) is equal to 600 and  $K = 2$ , then  $\theta = \tan^{-1}(2/600) \approx 0.19098$  degrees.

**[0044]** Referring now to Fig. 6, the point array 410 of Fig. 5 is illustrated with a larger angle  $\theta$ . In contrast to Fig. 5, the present figure depicts an example where  $K = 3$ . This means that there is redundancy such that three points 416 from the array 410 fall on the same scan line 418 (i.e., there is a three to one correspondence between three points 416 and a scan line 418). For example, the points (8,1), (7,5), and (6,9) are associated with the same scan line 418.

**[0045]** The distance "D" separates each point 416 from the adjacent points 416. As in Fig. 5, the total distance between the first and last points 416 in each row is equal to  $(M-1)*D$ , while the total distance between the first and last points

416 in each column is  $(N-1)*D$ . Using  $M, N, K, D$  and  $\theta$ , a series of relationships may be developed for  $K=3$ . As in Fig. 5, the relationships enable various aspects of the rotation of the array 410 to be calculated in order to achieve a desired result.

[0046] The distance "B" designates the distance between the scan lines 418 of two points in a row separated by two other points 416 when the array 410 is rotated to angle  $\theta$ . For example, the point (13,12) is separated from the point (16,12) by the distance B, which may be calculated as  $B = K*D*\cos(\theta)$ . The distance "C" may be calculated as  $C = D*\sin(\theta)$ . The distance "A" may be calculated as  $A = B-(N-1)*D*\sin(\theta)$ . A distance "R" represents the distance between redundant points 416 on a scan line 418. For example, the point (15,5) is separated from the point (14,9) by the distance R. A distance "E" designates the distance between the scan lines 418 of two adjacent points in a row when the array 410 is rotated to angle  $\theta$ , and may be calculated as  $E = C*N/K$ .

[0047] When the points 416 are uniformly distributed (i.e., the same distance separates each point 416 from the adjacent points 416 when projected onto the subject), then  $A=C=D*\sin(\theta)$ ,  $N/K$  is an integer, and  $\tan(\theta) = K/N$ .

[0048] Additional relationships may be developed using the above described equations.

$$\cos^2 = N^2 / (N^2 + K^2)$$

$$\sin^2 = k^2 / (N^2 + K^2)$$

$$R/C = 1 + (N/K)^2$$

$$R = C * (1 + (N/K)^2)$$

[0049] Using one or more of these relationships, the angle  $\theta$  can be calculated to achieve a desired distance between the scan lines 418. For example, when N (the number of rows) is equal to 600 and  $K = 3$ , then  $\theta = \tan^{-1}(3/600) \approx 0.286$  degrees.

[0050] Angles for different relationships may be calculated by applying the above described equations. For example, if  $N = 600$  and  $K = 20$ , then  $N/K = 30$ , which is an integer. Therefore, there is a uniform distribution of points on the substrate surface and the angle  $\theta$  may be calculated from  $\tan(\theta) = K/N$ . In this instance,  $\theta \approx 1.91$  degrees.

[0051] Referring now to Fig. 7, in one embodiment, a point array 710 (such as is embodied by a rotated DMD) is illustrated as an overlay on a memory 712 (shown as an exemplary memory grid). The point array 710 comprises M columns and N rows, where  $M=24$  and  $N=15$ . For purposes of illustration, the memory 712 comprises an S column by T row grid 718 of memory locations 714. The memory 712 may be contiguous (as illustrated) or non-contiguous.

[0052] The memory 712 includes an image (not shown) such as may be used for a photolithographic mask. Therefore, portions of the image are located at appropriate S,T locations 714 in the memory 712. Individual points 716 of the array 710 are illustrated overlaying memory locations 714 so as to reflect the rotation of the array 710 (i.e., located in such a way that each point 716 can be identified by a set of S,T coordinates). The rotation of the array 710 is such that  $K = 3$ , which means that three points 714 from the array 710 are in the same memory column S.

[0053] The size of the memory grid 712 is  $130 \times 94$ , which may be calculated as follows:

$$S = N + (M-1)*N/K = 15 + (24-1)*15/3 = 130$$

$$T = M + (N-1)*N/K = 24 + (15-1)*15/3 = 94.$$

[0054] Image data for the point array 710 may be retrieved memory row T by memory row T from the memory 712 and projected onto a subject (not shown). It is noted that a memory row T may not be equivalent to a point array row N, as the point array 710 has been rotated. As each memory row T is retrieved, a pointer 718 representing a starting address for the retrieved memory row T is updated to the address for the next memory row T to be retrieved. It is apparent that alternate retrieval strategies may be implemented to achieve the same result. For example, it may be preferable to retrieve multiple rows simultaneously, or it may be advantageous to retrieve the point array from memory on a column by column basis.

[0055] The point array 710 with its respective points 716, as illustrated in Fig. 7, may be viewed as a single "frame" in a scanning process. Each point 716 would then represent a corresponding pixel in the image stored in the underlying memory location 714. Therefore, each memory location 714 would appear in its respective position when the frame is projected onto a subject. This process is described in further detail with respect to Fig. 8.

[0056] Referring now to Fig. 8, an exploded view of a portion of the point array 710 overlay of Fig. 7 is now illustrated. The view illustrates an exemplary frame sequence for the point array 710. The points 716 of point array 710 are illustrated as a series of frames 810-822. Although the exploded view does not show each point 716, the frames 810-822 each include a set of 24x15 points 716 having a similar shading. Therefore, Fig. 8 illustrates seven frames 810-822. Each frame 810-822 includes the points 716, but the location of the points relative to the underlying image is altered as the point array 710 is scanned. For example, the frame 810 includes the topmost set of points in each group of seven, while the frame 812 includes the second set of points, and so on.

[0057] Referring now to Fig. 9, a final row of memory overlaid by the array 710 of Fig. 7 is illustrated as the current address of the pointer 718. A portion of memory for a second array 910 is visible and will be retrieved next starting with the bottom row. It is noted that a single point array may utilize a large amount of memory, and multiple arrays utilize increasingly large amounts of memory. In addition, a high rate of retrieval should be maintained for optimal projection results.

[0058] Referring now to Figs. 10a-b, an example of a benefit afforded by the higher resolution provided by the present invention is illustrated. Referring now specifically to Fig. 10a, a pixel panel (not shown) is operable to project a point array 1010 at a resolution of 3.4 micrometers ( $\mu\text{m}$ ). The point array includes "full" pixels 1012 which may represent pixels for circuit components and "empty" pixels 1014 which represent empty space in which no circuit component is present. This may be accomplished with a frame rate of approximately 5000 frames per second (5 Kfps) at a data rate of approximately 450 KB per pixel panel. As previously described, the resolution of the projected image is typically limited by the resolution of the pixel panel.

[0059] Referring now specifically to Fig. 10b, rotating the pixel panel such that  $K = 30$  enables the same portion of the point array 1010 to be projected at a higher resolution of  $0.85 \mu\text{m}$ . Therefore, in the present example, rotating the point array 1010 provides a level of resolution that is four times greater than the native resolution of the pixel panel. This means that each pixel 1012, 1014 of Fig. 10a is now represented by sixteen pixels in Fig. 10b. This may allow edges to be smoothed and similar desirable refinements to be made to the circuit.

[0060] Referring now to Fig. 11, one embodiment of a system 1110 for real time data extraction and manipulation is illustrated. The system 1110 may be incorporated in another system, such as the system 100 of Fig. 1, or it may be a



stand alone system. In the present embodiment, the system 1110 includes a personal computer (PC) 1112, an interface 1114, an image memory 1116, a plurality of digital signal processing (DSP) devices 1118, a frame buffer 1120, and a DMD 1122. The PC, utilizing the interface 1114, may interact with and/or control aspects of the system 1110.

[0061] For purposes of illustration, the system 1110 utilizes point arrays 1124 (not shown) of  $M = 848$  columns and  $N = 600$  rows, such as are described in relation to Figs. 4-9. The point arrays 1124 may be combined to form an image 1126 (not shown), and so each point array 1124 may be viewed as a single frame of the image 1126. Each point array 1124 includes a plurality of points 1128. Each DSP device 1118 operates in a similar manner, and so a single exemplary DSP device 1118 is described below. In the present embodiment, the DMD 1122 is rotated so that  $K = 30$ , as has been previously described and has a native resolution of 848 pixels by 600 pixels.

[0062] The memory size needed to store an  $848 \times 600$  point array (a frame) may be calculated by inserting the values for  $M$ ,  $N$ , and  $K$  into the previously described equations. Doing so results in a memory size of:

$$S = N + (M-1)*N/K = 600 + (848-1)*600/30 = 17540$$

$$T = M + (N-1)*N/K = 848 + (600-1)*600/30 = 12828$$

or  $17540 \times 12828$ . This can be viewed in terms of storage as approximately twenty-eight megabytes (MB).

[0063] In operation, the DSP device 1118 extracts a discrete unit, such as a frame embodied in one of the point arrays 1124, from the image 1126. The DSP device 1118 then calculates a position on the DMD 1122 for each point 1128 of the point array 1124. Because the DMD 1122 is rotated in relation to a subject 1130

(not shown), the position of each point 1128 should enable proper projection of the associated point array 1126.

[0064] After the DSP device 1118 has calculated the DMD positions of the points 1128, the frame is transferred to the frame buffer 1120. In the current embodiment, the frame buffer 1120 is capable of storing a single 848 x 600 frame, which is approximately 62.1 kilobytes (KB) of data. The frame buffer 1120 then transfers the frame to the DMD 1122, where the frame is projected onto a subject. It is noted that a plurality of frame buffers 1120 may be utilized for increased efficiency and throughput. For example, dual frame buffers 1120 may be utilized so that, while one frame buffer is receiving data from the DSP device 1118, the other frame buffer is transferring its data to the DMD 1122.

[0065] Referring now to Fig. 12, another embodiment of a system 1210 for real time data extraction is illustrated. The system 1210 may be incorporated in another system, such as the system 100 of Fig. 1, or it may be a stand alone system. In the present embodiment, the system 1210 includes a PC 1212, an interface 1214, an image memory 1216, a DSP device 1218, a shift register 1220, a frame buffer 1222, and a DMD 1224.

[0066] The PC, utilizing the interface 1214, may interact with and/or control aspects of the system 1210. The shift register 1220 may be a single shift register or may be a plurality of shift registers suitable for a desired operation. For purposes of illustration, the shift register 1220 is a 64x53 bit register (i.e., it includes 53 registers operable to store 64 bits each). The DMD 1224 in the system 1210 includes a 53 bit data path, although other data path sizes may be used as desired, and has a native resolution of 848x600. The frame buffer 1222 includes a capacity for sixty-four 848x600 frames.

[0067] As in Fig. 11, the system 1210 utilizes point arrays 1226 (not shown) of  $M = 848$  columns and  $N = 600$  rows. The point arrays 1226 may be combined to form an image 1228 (not shown), and so each point array 1226 may be viewed as a single frame of the image 1228. Each point array 1226 includes a plurality of points 1230. In the present embodiment, the DMD 1224 is rotated so that  $K = 30$ , as has been previously described.

[0068] The memory size needed to store an  $848 \times 600$  point array (a frame) may be calculated by inserting the values for  $M$ ,  $N$ , and  $K$  into the previously described equations. Doing so results in a memory size of:

$$S = N + (M-1)*N/K = 600 + (848-1)*600/30 = 17540$$

$$T = M + (N-1)*N/K = 848 + (600-1)*600/30 = 12828$$

or  $17540 \times 12828$ . This can be viewed in terms of storage as approximately 28 megabytes (MB).

[0069] In the present embodiment, the DSP device 1218 selects and extracts 64 bits of data from the memory 1216. The selection and extraction of data may be done by row or column, or by some other method. The DSP device 1218 then calculates the location for each of the 64 bits on the DMD 1224, and transfers the data into one of the 64 bit registers of the shift register 1220. The DSP device 1218 continues with this selection, extraction, calculation, and transfer process until all 53 of the 64 bit registers of the shift register 1220 are full.

[0070] The contents of the shift register 1220 are then transferred to the frame buffer 1222. Since each of the 64 frames included in the frame buffer 1222 is  $848 \times 600$ , the contents of the shift register 1220 may not be sufficient to fill a frame. Therefore, the process involving the DSP device 1216, the shift register 1220, and the frame buffer 1222 may be repeated until each frame of the frame

buffer 1222 is filled. After 64 frames (or less, if 64 frames are not available) are stored in the frame buffer 1222, the frames are transferred to the DMD 1224 and projected onto a subject. The process then begins again in order to retrieve more data for the DMD 1224 as is illustrated in Fig. 13.

[0071] Referring now to Fig. 13, a method 1310 suitable for application to the system 1210 of Fig. 12 is illustrated. In step 1312, the method calculates an address for 64 bits, which determines the location of each bit on the DMD 1224. The 64 bits are then retrieved from the memory 1216 in step 1314 and sent to the register 1220 in step 1316. Once this process occurs 53 times, as determined in step 1318, the data is shifted into the frame buffer by column (i.e., 53 bits at a time) in step 1320. For example, the most significant digit (or least, depending on the endian ordering) of all 53 registers are shifted in the first frame, while the second most (or least) significant digits of all 53 registers are shifted into the second frame and so on, until all 64 bits have been shifted into an appropriate frame. Therefore, a total of 64 shifts will be utilized to fully clear the shift register 1220.

[0072] If the frames of the frame buffer 1222 are not full as determined in step 1322, the process returns to step 1312. This continues until the frames are full or until all the data has been transferred from the memory 1216. When the frames are full, the data is transferred for each frame in sequential order to the DMD 1224 in step 1324. If image data remains to be transferred as determined in step 1326, the process returns to step 1312. It is noted that the ordering of some steps of the method 1310 may be altered and that certain steps may be modified or removed. For example, it may be preferable to retrieve the 64 bits from the memory before calculating the addresses. In addition, it may be preferable to calculate a single address for each retrieved set of bits, rather than for each bit.

These and other alterations may depend on a particular implementation of the system 1210, and so the described system and method are merely exemplary.

[0073] Referring again to Fig. 12, it is noted that a plurality of frame buffers 1222 may be utilized for increased efficiency and throughput. For example, dual frame buffers 1222 may be utilized so that, while one frame buffer is receiving data from the shift register 1220, the other frame buffer is transferring its data to the DMD 1224. The system 1210 utilizes a relatively small amount of memory, but certain steps may be repeated in order to retrieve all of the frames.

[0074] Referring now to Fig. 14, yet another embodiment of a system 1410 for real time data extraction is illustrated. The system 1410 may be incorporated in another system, such as the system 100 of Fig. 1, or it may be a stand alone system. In the present embodiment, the system 1410 includes a line buffer 1412, a DSP device 1414, a frame buffer 1416, a selector 1418, and a DMD 1420. The DMD 1420 in the system 1410 includes a 53 bit data path, although other data path sizes may be used as desired, and has a native resolution of 848x600. The frame buffer 1416 is operable to hold a plurality of 848x600 frames for an image 1422 (not shown).

[0075] As in Fig. 11, the system 1410 utilizes point arrays 1424 (not shown) of  $M = 848$  columns and  $N = 600$  rows. The point arrays 1424 may be combined to form the image 1422 (not shown), and so each point array 1424 may be viewed as a single frame of the image 1422. Each point array 1424 includes a plurality of points 1426. In the present embodiment, the DMD 1420 is rotated so that  $K = 30$ , as has been previously described.

[0076] In the present embodiment, the line buffer 1412 receives lines of data from a memory (not shown). For example, the line may be a row of memory such was described in relation to Fig. 7. The data line is retrieved from the line

buffer 1412 by the DSP device 1420. The DSP device 1414 calculates the address for the line data so that its location on the DMD 1420 is known. The DSP device 1414 then transfers the line data into the frame buffer 1416. This process continues until all the line data has been placed into the appropriate frames. Therefore, the frame buffer 1416 includes a total number of frames for the image 1422.

[0077] After the line data is stored in the frame buffer 1416, the selector 1418 selects a frame and transfers the selected frame to the DMD 1420 for projection. This selection may be sequential or may use some other criteria for the order in which frames are selected and transferred.

[0078] It is noted that modifications to the system 1410 may be made as desired. For example, it may be desirable for the selector to transfer frames as they are filled, rather than waiting for the frame buffer 1416 to completely fill before beginning the selection and transfer process. In addition, the DSP device 1414 may insert the line data into the frames in a variety of ways. For example, the DSP device 1414 may insert the entire line into a single frame, or it may insert individual bits of the line data into appropriate but different frames.

[0079] The system 1410 may utilize more memory than some systems (for example, the system 1210 of Fig. 12), but is operable to prepare all the frames of an image for transfer at one time. Therefore, different systems may be used to accomplish different goals. In addition, systems or portions of systems may be combined so as to gain particular benefits as desired.

[0080] It is noted that memory usage may be effected by the value selected for K. As is illustrated below, a smaller K generally results in higher memory consumption, while a higher K results in a lower memory consumption.

[0081] For example, a point array of 848x600 with  $K = 30$  should have a memory array of 17540x12828, as calculated previously. A line buffer operable to buffer a complete line of data will need memory for 17540 bits, or approximately 3.3 KB. A frame buffer operable to hold all the frames should have a memory allowance for 12828x848x600 bits, or 816 MB.

[0082] In contrast, the same point array of 848x600, but with  $K = 20$ , should have a memory array of 26010x18818. A line buffer operable to buffer a complete line of data will need memory for 26010 bits, or approximately 3.3 KB. A frame buffer operable to hold all the frames should have a memory allowance for 18818x848x600 bits, or 1.2 gigabytes (GB).

[0083] While the invention has been particularly shown and described with reference to the preferred embodiment thereof, it will be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention. For example, it is within the scope of the present invention that alternate types and/or arrangements of DSP devices, buffers, registers, and/or other components may be used. Furthermore, the order of components may be altered in ways apparent to those skilled in the art. Additionally, the type and number of components may be supplemented, reduced or otherwise altered. Other uses are also foreseen, such as digital projection and image manipulation and display. Therefore, the claims should be interpreted in a broad manner, consistent with the present invention.